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NUMERICAL COMPUTATION OF SPACE SHUTTLE ORBITER FLOW FIELD

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SEMI-ANNUAL STATUS REPORT

This report summarizes the research accomplished under NASA Grant NAG-2-245 during the period April 1, 1984 through September 30, 1984.

In this study, the complete inviscid-viscous real gas flow around the Space Shuttle Orbiter is being computed. Real gas effects are especially important in predicting the re-entry environment around the Orbiter because the high temperatures within the shock layer cause the air to dissociate and ionize, thus invalidating the perfect gas assumption. Maus et al.[1] have shown that real gas effects can have a significant influence on the Orbiter aerodynamics. The present approach utilizes a time-dependent Navier-Stokes code to compute the subsonic nose portion of the flowfield. This nose solution provides the initial conditions for the "parabolized" Navier-Stokes (PNS) code which subsequently marches the solution downstream to the final station.

During the present reporting period, the generalized PNS solver of Tannehill et al[2-3] was modified to permit equilibrium air calculations The required thermodynamic and transport properties of equilibrium air are obtained from the simplified curve fits developed by Tannehill and associates[4-6] or from the table look-up procedure of the NASA RGAS program[7]. To date, all calculations have utilized the assumption that the ratio of specific heats (γ) and the transport properties (μ,k) remain locally constant during each step of the marching procedure. With this approximation, the Jacobians in the numerical algorithm have the same functional form for both a real gas and a perfect gas, but of course, have different numerical values since the thermodynamic and transport properties are obtained from the real gas data. During the previous reporting period the three-dimensional, time-dependant, blunt body code of Kutler et al.[8-9] was also modified to permit equilibrium air calculations.

The two real gas codes were used to compute the laminar flow of equilibrium air around the forebody of the Orbiter. The flow conditions chosen for the computation correspond to the flight conditions at one point of the STS-3 trajectory (t = 595 s after re-entry) where the altitude and velocity were 71.32 km and 6.74 km/s, respectively. The corresponding flow conditions are:

$M_\infty = 20.99$	$Pr_\infty = 0.72$
$\alpha = 40.05^0$	$T_\infty = 256.7^0$ K
$Re_L = 8.816 \times 10^5$	$T_{wall} = 1100.^0$ K
$\gamma_\infty = 1.40$	

The Orbiter flow field was computed for both an ideal gas ($\gamma = 1.2$) and equilibrium air using the above flight conditions. Comparisons were made with flight data wherever possible. The results from the "effective gamma" and equilibrium air calculations were in excellent agreement for wall pressures, heat transfer rates, and shock shapes. In addition, the numerical results agreed closely with the measured flight data for wall pressures and heat transfer rates. The agreement with the heat transfer data was probably fortuitous since the present equilibrium algorithm assumes a fully catalytic wall in contrast to the noncatalytic surface of the Orbiter. In addition, a constant wall temperature of 1100^0K was assumed which should lead to additional differences. The present results were presented[10] at the AIAA 19th Thermophysics Conference in Snowmass, Colorado, June 27, 1984.

During the next reporting period, work will be initiated to improve the present computational procedure by including the following additional features:

1. Exact Shuttle geometry
2. Nonequilibrium chemistry
3. Precise wall boundary conditions

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